DAG-TM
Concept Element 11: "Self Separation for Merging and In-Trail Operations" for Terminal Arrival Operations

LaRC Research and Development Activities

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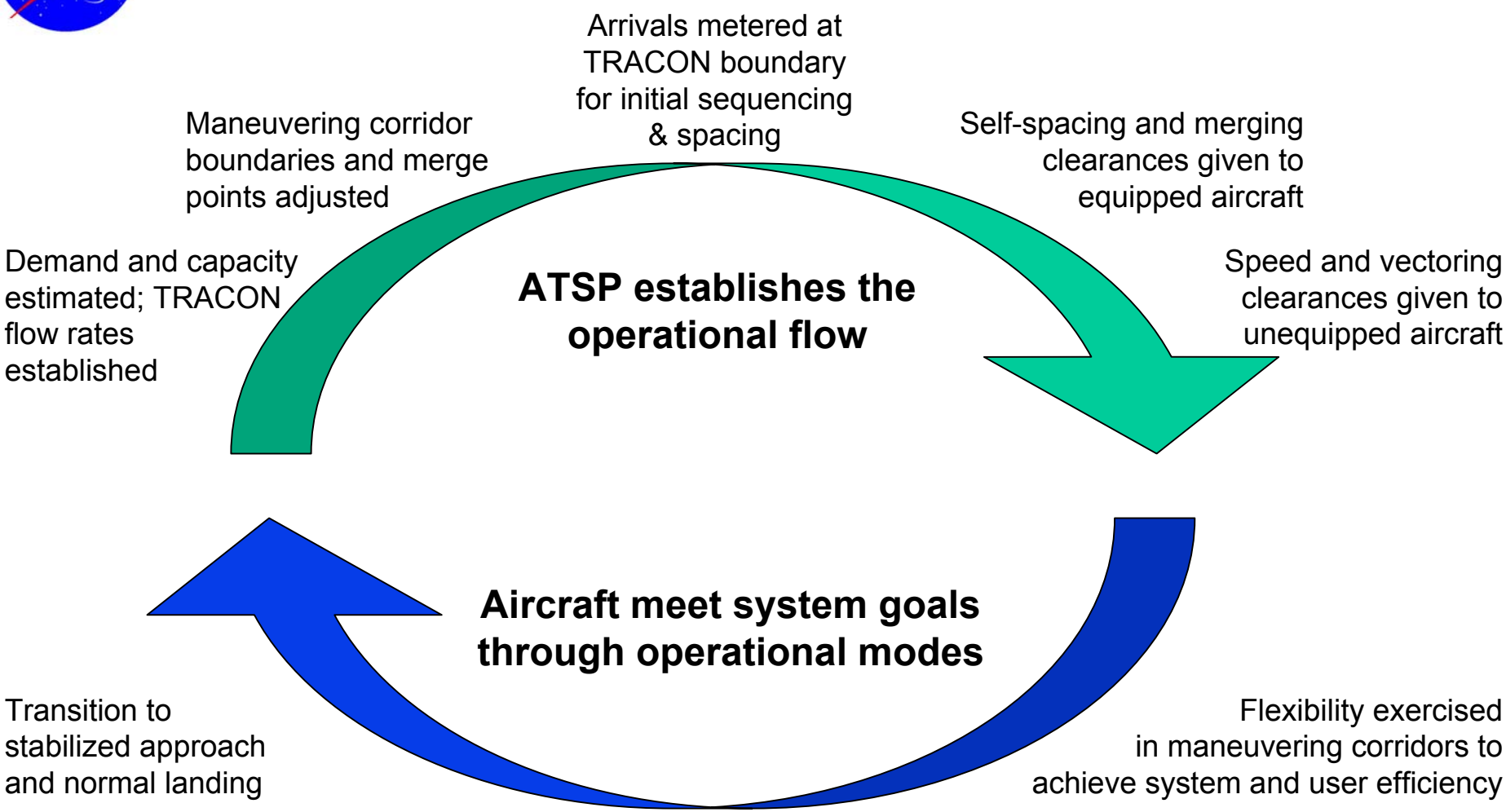
Gary W. Lohr
Crew/Vehicle Integration Branch
NASA Langley Research Center
Hampton, VA 23681-2199
(757) 864-2020
E-mail: g.w.lohr@larc.nasa.gov

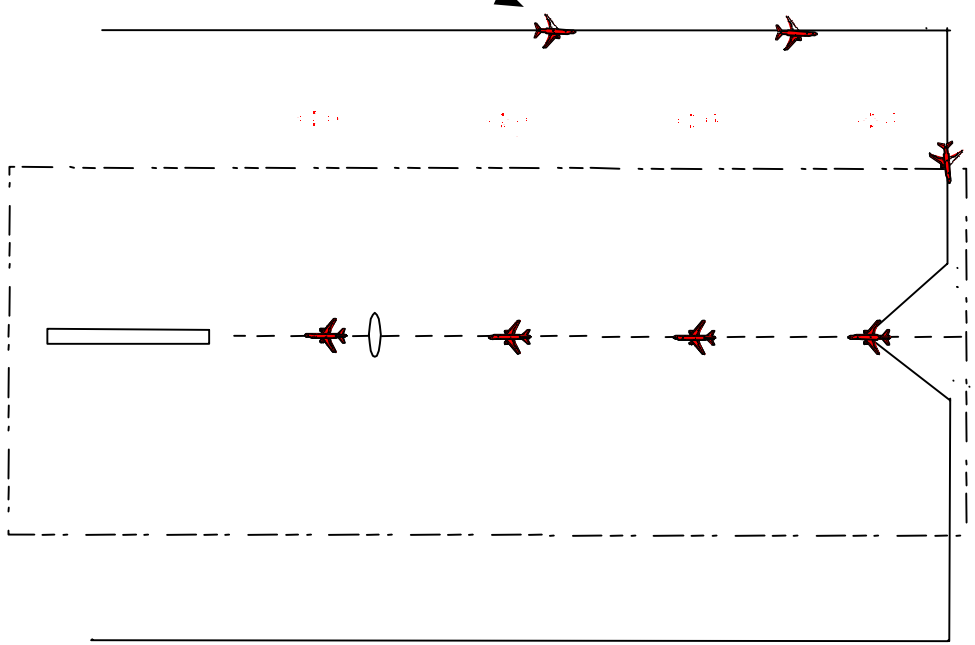
Terminal Arrival Concept

DAG-TM - Terminal Arrival Concept and Research



In Trail Self-Spacing

Following aircraft self spacing at specified interval, e.g."80 seconds"



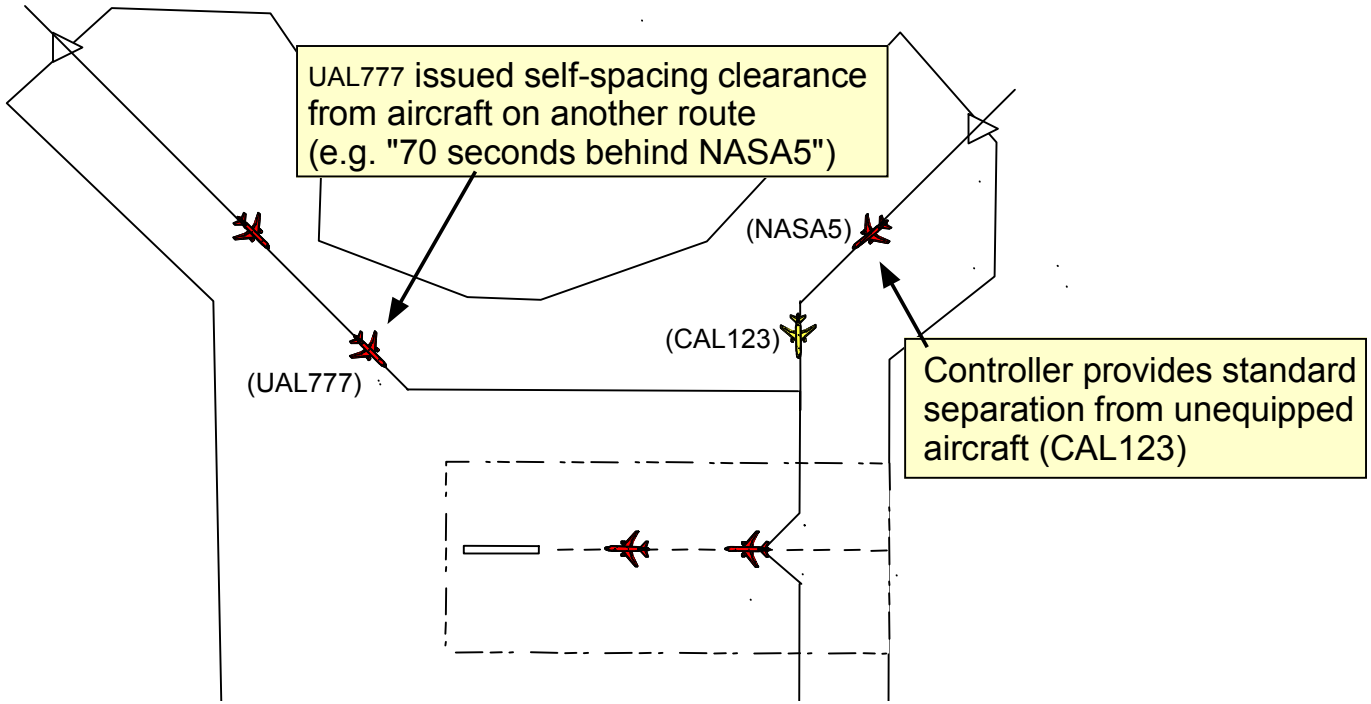
A self spacing clearance could be issued when an aircraft enters the terminal area

Key: Equipped (data link and appropriate automation)

In trail self-spacing characteristics

- self-spacing along structured routes
- self-spacing operation must accommodate a stabilized approach

Merging



"Merging" characteristics

- structured routes
- sequence provided from ground

Key:
- Equipped (data link and appropriate automation)
- Unequipped

Maneuvering

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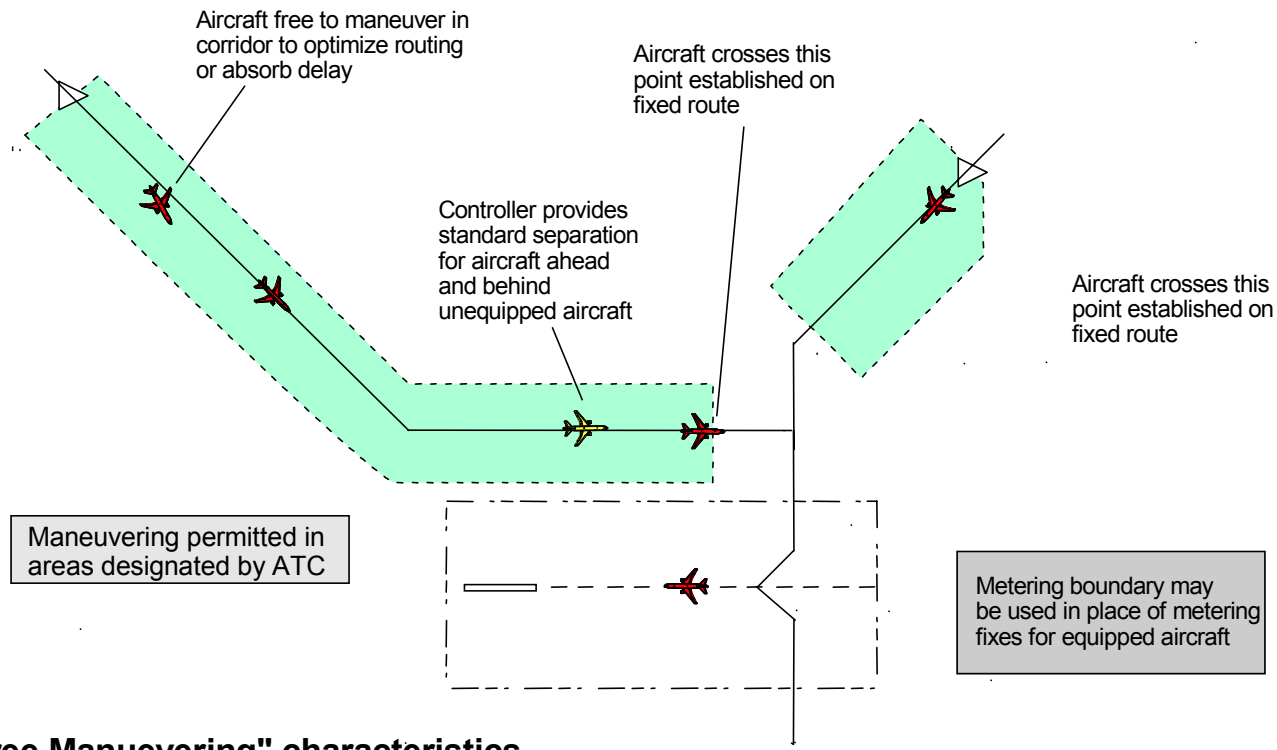


"Free Manuevering" characteristics

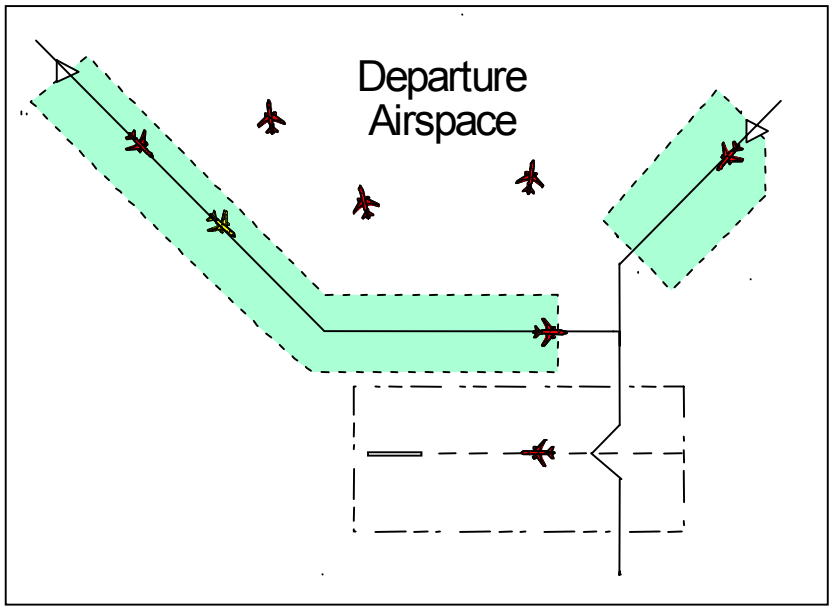
- unstructured route
- designated corridors/zones defined in which free maneuvering is permitted

Key:
- Equipped (data link and appropriate automation)
- Unequipped

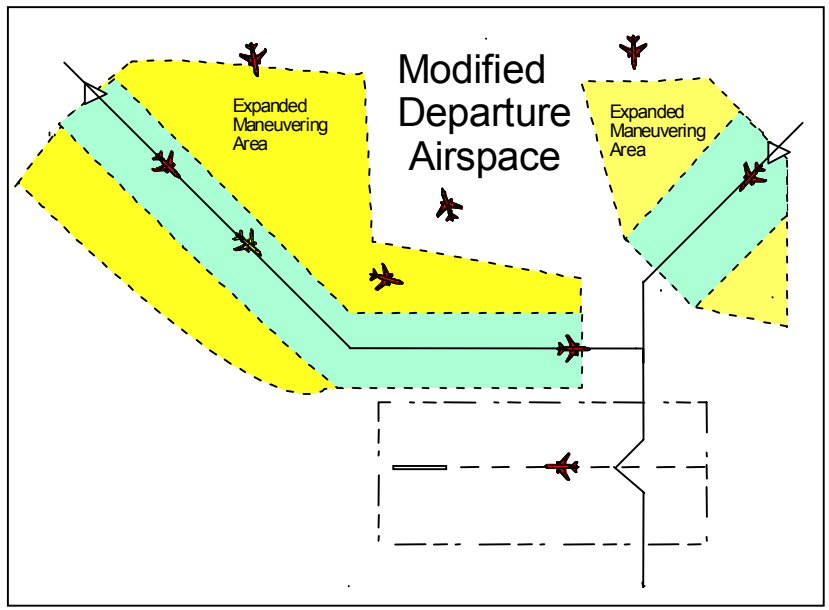
Expanded Maneuvering Area

Expanded Maneuvering Areas

Applicable in terminals with unbalanced arrival/departure traffic periods; during periods of heavy arrival traffic, sections of departure airspace is designated as Maneuvering Areas for arrival traffic.



Nominal Airspace Configuration



Airspace redefined to allow added maneuvering flexibility for arrivals

LaRC CE-11 In-House Team Expertise

- Pilot
- Flight Deck Systems Design
- ATC/NAS
- Algorithm development
- Human factors
- Flight operations numerical analysis

Concept Development and Supporting Research Activities

LaRC Approach Spacing Research

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- **Past History**
  - NASA has 30 years experience in approach spacing research
  - Early work was done with the Terminal Configured Vehicle (TCV) in the early ‘70s
  - Timed based spacing algorithms developed as part of Cockpit Display of Traffic Information (CDTI) work
- **Current Work: Self Spacing Algorithm Development**
  - Monte Carlo Analysis was used in the refinement of spacing algorithms
  - “time based” was deemed to demonstrate the most promise

LaRC Approach Spacing Research (cont.)

- **Current Work (con't)**
  - Self spacing algorithms flown as part of the SafeFlight 21 Operational Evaluation (OpEval) 2 conducted in Louisville, KY, October, 2000
    - algorithms functioned as designed
    - provided early experience with real avionics in a live operational environment
    - good operational data indicates that enhancements to the algorithms are required

- **Near Term Work**
  - Simulation planned to evaluate spacing accuracy and candidate procedures
  - Modified algorithms for in-trail and merging applications to be flown on Langley's B757 as part of the SafeFlight 21 OpEval 3 in Memphis

FAA OpEval 2

OpEval 2: Evaluation of ADS-B

- Self Spacing Application Objectives:
  - Evaluate ADS-B for Approach Spacing
  - Assess CDTI for delivering consistent interval at runway threshold

- Time based spacing algorithms flown on two business jets
- Speed bug on PFD driven by self-spacing algorithm

LaRC Approach Spacing Research (cont.)

- **Current Work (con't)**
  - Self spacing algorithms flown as part of OpEval 2 conducted in Louisville, KY, October, 2000
    - algorithms functioned as designed
    - provided early experience with real avionics in a live operational environment
    - test data indicates that enhancements to the algorithms are required
- **Near Term Work**
  - Simulation planned to evaluate spacing accuracy and candidate procedures
  - Modified algorithms for in-trail and merging applications to be flown on Langley's B757 as part of the SafeFlight 21 OpEval 3 in Memphis

LaRC Approach Spacing Research (cont.)

- **Long Term Work**
  - Investigate airspace design issues (e.g. maneuvering corridors) in various airspace configurations including multiple merge scenarios
  - Investigate the feasibility of maneuvering in designated airspace
  - Investigate the integration of RTAs into terminal area operations
  - Integration of noise sensitive approach profiles into self-spacing and maneuvering operations
  - Investigate integration of self spacing and maneuvering operations with capacity increases resulting from Aircraft Vortex Spacing System (AVoSS)

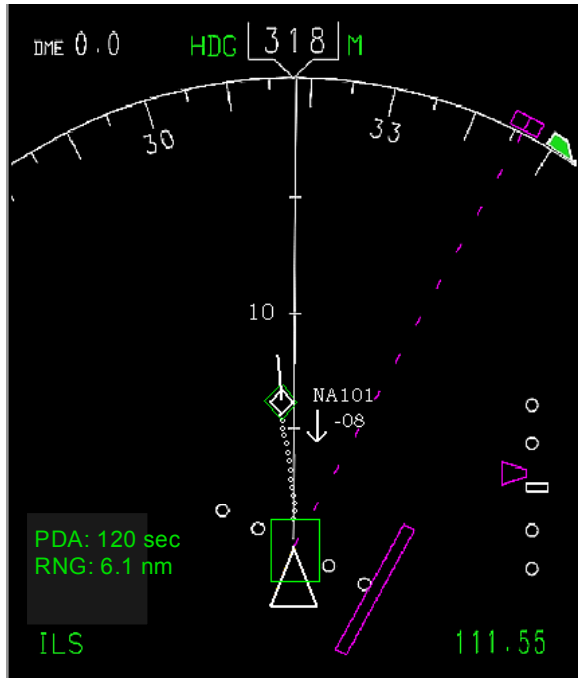
Langley Self-Spacing Algorithm

- Provides speed commands to obtain a desired runway threshold crossing time (relative to another aircraft)
- Compensates for dissimilar final approach speeds between aircraft pairs
- Includes wake vortex minima requirements
- Provides operational reasonable speed profiles
- Provides guidance for stable final approach speed
- Original algorithm flown during FAA Safe Flight Op Eval II (Oct 2000)

Langley goals for crew procedures and supporting interfaces for Modes 1 & 2

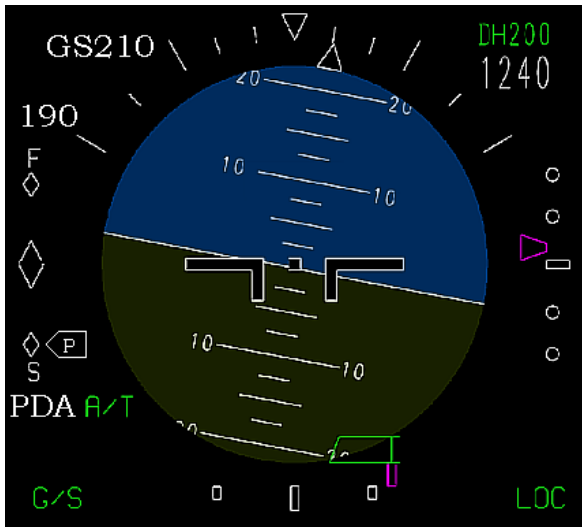
- minimize changes
- make it look like a "normal op"

Navigation Display after target selection



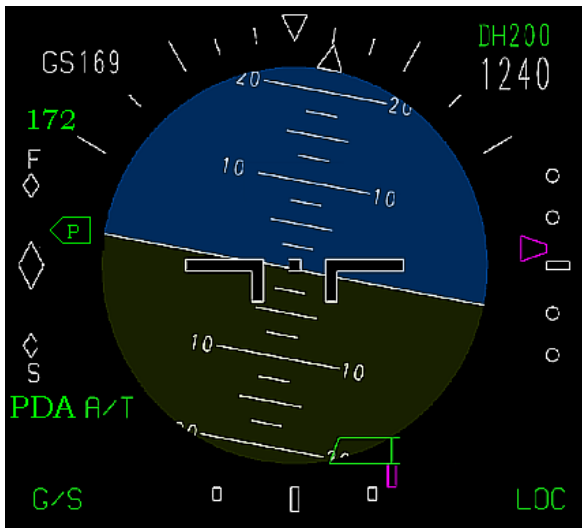
Displayed situation:
- 6.1 nm horizontal range
- 120 second desired threshold crossing time interval
- behind desired position (time box)

EADI after speed guidance selected (before speed capture)



Displayed situation:
- PDA speed guidance is ARMED
- current speed is below desired speed

EADI after speed guidance selected (after speed capture)



Displayed situation:
- PDA speed guidance is ENGAGED
- command speed is 172 kts
- current speed is slightly above desired speed

Advanced Terminal Area Self Spacing (ATASS) Piloted Simulation Study

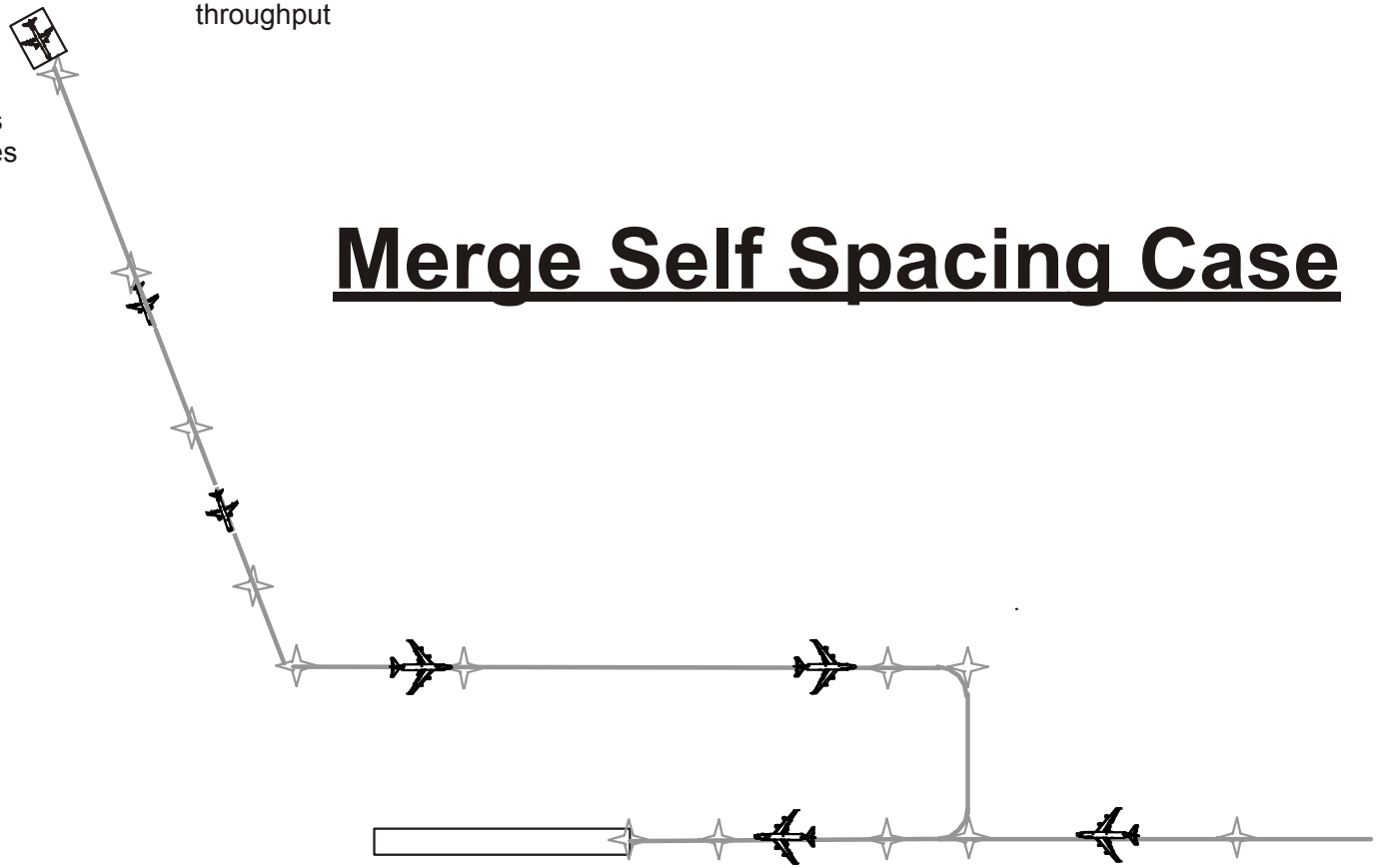
Objectives

- **Pilot evaluation (acceptability) of:**
  - procedure (including issuance of clearance and accepting responsibility for spacing)
  - display (information on ND and PFD)
  - interface (target selection and arming of system)
- **Evaluation of algorithm performance when implemented on "real-world" equipment**
- **Pilot assessment of workload**

A/C are delivered to metering fixes in a position to ensure maximum runway throughput

A/C assumed to have ATIS which advertises self spacing clearances

Merge Self Spacing Case

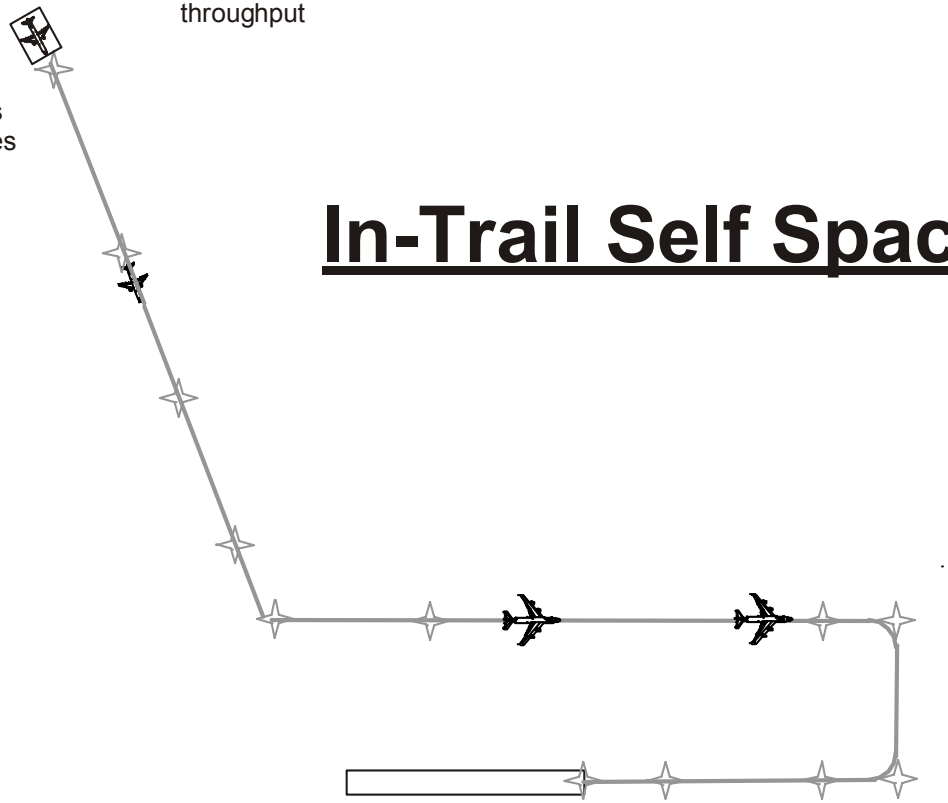


(Final Approach Fix)

A/C are delivered to metering fixes in a position to ensure maximum runway throughput

A/C assumed to have ATIS which advertises self spacing clearances

In-Trail Self Spacing Case



(Final Approach Fix)

Flight Deck Simulators

Research Flight Deck

Integration Flight Deck

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NASA B-757 aircraft
NASA Langley Research Center 6/18/1996 Image # EL-1999-00109

Air Traffic Operations Lab

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Flight Deck Research Station & Transport Research System

- *Two-crew evaluations*
- *Realistic visual scene for terminal area experiments*
- *Flexible Evaluation Environment*

Part Task Simulator

- *Integration testing & sim results validation*
- *Tests for which no good simulation exists*

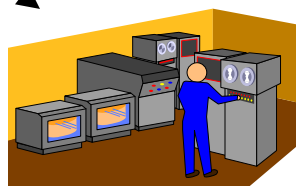
validation or refinement

Research Concept

Software development

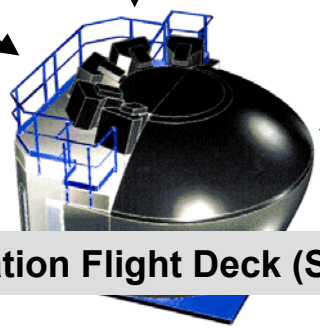
Research Flight Deck (Simulator)

Possible Software modification



concept "screening"

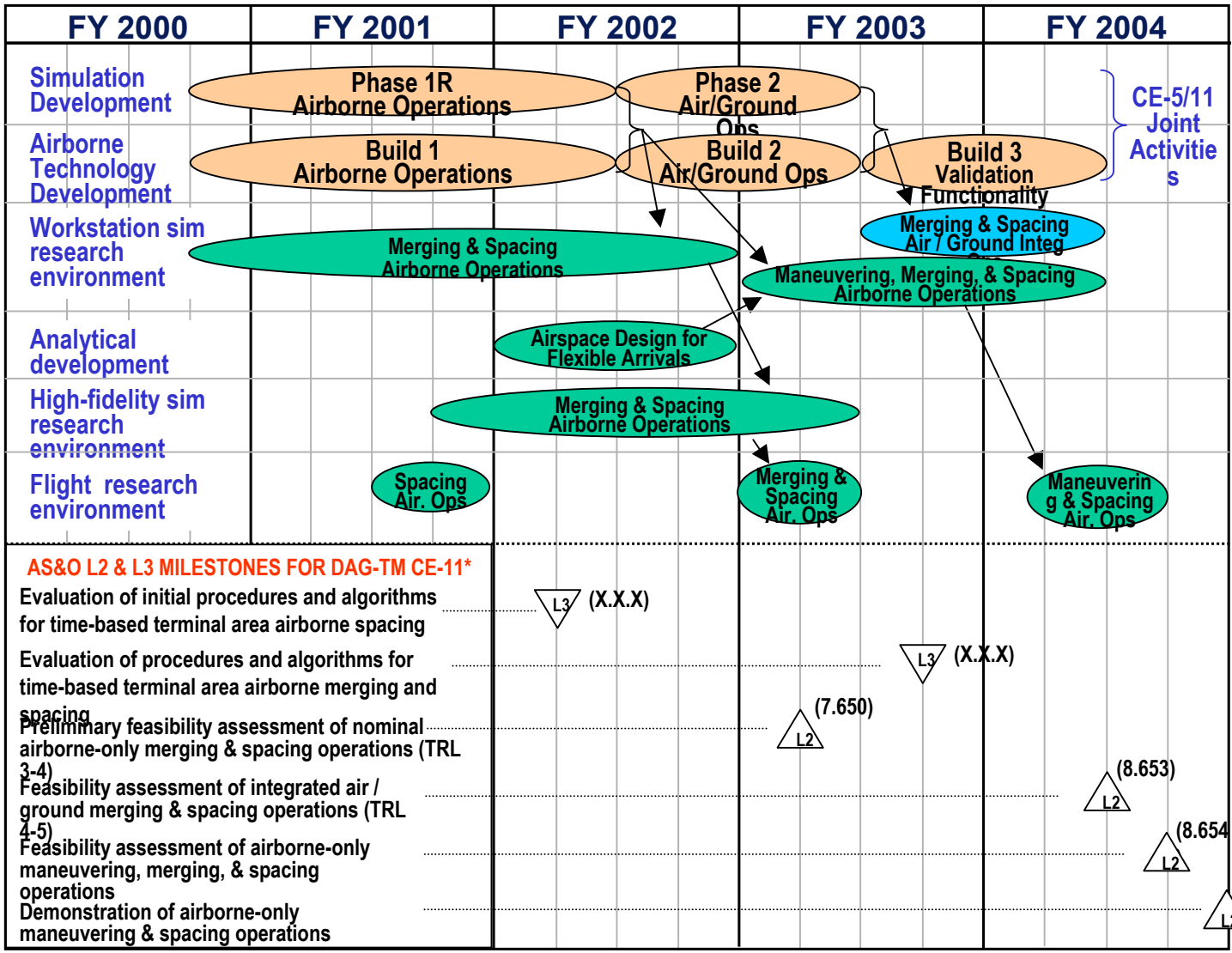
Research Systems Integration Lab (RSIL)



Integration Flight Deck (Simulator)

- *Research System development and checkout (off airplane, with researcher participation)*
- *"Virtual Presence" participation in flight tests*

AS&O CE-11 Plan



*Joint development milestones with CE-5 are shown only in CE-5 plan